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HEALTH INFORMATION TECHNOLOGY

Clinical Benefits of Electronic Health Record Use: National Findings

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Objective. To assess whether physicians' reported electronic health record (EHR) use provides clinical benefits and whether benefits depend on using an EHR meeting Meaningful Use criteria or length of EHR experience.

Data Source. The 2011 Physician Workflow study, representative of U.S. office-based physicians.

Study Design. Cross-sectional data were used to examine the association of EHR use with enhanced patient care overall and nine specific clinical benefits.

Principal Findings. Most physicians with EHRs reported EHR use enhanced patient care overall (78 percent), helped them access a patient's chart remotely (81 percent), and alerted them to a potential medication error (65 percent) and critical lab values (62 percent). Between 30 and 50 percent of physicians reported that EHR use was associated with clinical benefits related to providing recommended care, ordering appropriate tests, and facilitating patient communication. Using EHRs that met Meaningful Use criteria and having 2 or more years of EHR experience were independently associated with reported benefits. Physicians with EHRs meeting Meaningful Use criteria and longer EHR experience were most likely to report benefits across all 10 measures.

Conclusions. Physicians reported EHR use enhanced patient care overall. Clinical benefits were most likely to be reported by physicians using EHRs meeting Meaningful Use criteria and longer EHR experience.

Key Words. Information technology in health care, technology adoption, technology diffusion, technology use, ambulatory care

The Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 was designed to support diffusion of health information technology to improve patient care. HITECH authorized the Medicare and Medicaid EHR Incentive Programs which began providing incentive payments to physicians and hospitals that demonstrated *Meaningful Use* of EHRs in 2011. HITECH also established a national EHR certification program to certify the capability of EHRs to meet

Meaningful Use requirements. In 2011, over half of office-based physicians had adopted an EHR, and about three-quarters of adopters reported their EHR was certified to meet Meaningful Use criteria (Jamoom et al. 2012).

Understanding physician views about EHR impacts is important to evaluate and support progress toward the goals of HITECH. Physician perceptions of EHR usefulness is a key factor in their decision to adopt and use EHRs (Simon et al. 2007; Kralewski et al. 2008; Morton and Wiedenbeck 2009; Castillo, Martinez-Garcia, and Pulido 2010; Holden 2010; Holden and Karsh 2010; Denomme et al. 2011; McGinn et al. 2011). Much information about physicians' EHR experiences is anecdotal or based on studies of individual specialty groups, states, or health systems (Holroyd-Leduc et al. 2011). There is little recent nationally representative data on physician perceptions of EHR impacts and how physicians' experiences with EHRs differ based on key EHR-related characteristics.

This study used nationally representative survey data to examine perceptions of physicians who use EHRs, specifically the extent to which physicians reported EHR use provided clinical benefits and whether perceived benefits varied according to two EHR characteristics: whether their EHR system met Meaningful Use criteria and their length of experience with any EHR. The Meaningful Use criteria were selected to ensure EHRs could support improved safety, quality, and efficiency of patient care (Blumenthal and Tavenner 2010), and previous studies have found that perceptions of EHR usefulness improve as users acquire more EHR experience (El-Kareh et al. 2009; Devine et al. 2010; Shield et al. 2010; Holroyd-Leduc et al. 2011; Doyle et al. 2012). Therefore, we hypothesized that these two factors would have independent, positive associations with the probability of reporting clinical benefits. We also hypothesized that the *combination* of having an EHR that met Meaningful Use criteria and greater EHR experience would be associated with the highest probability of reporting benefits.

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METHODS

Data Sources and Analysis Sample

We used data from two nationally representative surveys of nonfederal office-based physicians in the United States: (1) the 2011 National Ambulatory Medical Care Survey (NAMCS) Electronic Health Records mail survey from which we obtained physicians' office characteristics and whether they used an EHR and (2) a follow-up mail survey, the 2011 NAMCS Physician Workflow Survey, that asked physician respondents about their attitudes and experiences with EHRs. The Physician Workflow Survey was developed with the guidance of an expert advisory panel; separate questionnaires were developed for physicians with and without EHRs.

The sample for the 2011 Physician Workflow Survey was all physicians confirmed eligible for the 2011 NAMCS Electronic Health Records Survey (i.e., nonfederal office-based physicians excluding radiologists, anesthesiologists, and pathologists). Eligibility status was determined for 8,164 of the 10,301 physicians sampled for the Electronic Health Records Survey; 5,232 of these physicians were deemed eligible and mailed the Physician Workflow questionnaire. A total of 3,180 physicians responded for an unweighted response rate of 60.8 percent.

Additional information on the survey methods is available elsewhere (Jamoom et al. 2012).

This analysis focused on perceptions of EHR adopters regarding clinical benefits of EHR use, using information collected from the adopter questionnaire. Thus, the analysis was limited to respondents who used an EHR at their primary practice location in 2011 (n = 1,793). After excluding observations with missing data on key independent variables, the final sample size was 1,727.

Dependent Variables

We assessed physician perceptions of EHR benefits based upon responses to 10 questions that asked whether use of their EHR provided specific clinical benefits (listed in Table 1). Response categories were as follows: "yes, within the past 30 days"; "yes, but not within the past 30 days"; "no"; and "not applicable." We created 10 dichotomous dependent variables that combined the two yes responses into one group and other responses ("no," "not applicable," and missing) into the other group. Across the 10 questions, responses were

missing for between 1 and 6 percent of physicians. "Not applicable" responses ranged from 2 to 15 percent; these responses may indicate that the specific clinical benefit was not applicable to the physician's scope of work or their EHR system. Because these physicians were included in the analysis, the estimates of EHR benefits may be conservative.

Key Independent Variables

The main independent variables of interest were (1) whether the physician's EHR met Meaningful Use criteria and (2) length of experience with any EHR system.

We created a dichotomous variable based on the question "Does your current system meet Meaningful Use criteria as defined by the Centers for Medicare & Medicaid Services (CMS)?" Response categories were "yes," "no," and "uncertain." Yes responses were considered to have EHRs that met Meaningful Use criteria.[1] The share of EHR adopters who reported their EHR met Meaningful Use criteria was nearly identical to non-self-reported results of another study (Office of Inspector General 2012). Our results were robust to sensitivity analyses using an alternate measure of Meaningful Use EHR.[2]

EHR experience was measured based on the item: "Estimate the approximate number of years you have used any EHR system." The analyses compared physicians with 2 or more years of experience to those with 1 year or less. Physicians that answered a noninteger number were rounded to the nearest whole year. Experience was missing for 66 physicians, excluded from the analysis.

Analyses

Univariate descriptive statistics were calculated to describe the percent of physicians who reported clinical benefits of EHR use. To assess our main hypotheses, we estimated a series of logistic regression models, one for each of the ten outcome variables described above:

$$\Pr(\text{Benefit}) = \beta_1 \text{MUEHR} + \beta_2 \text{Experience} + \beta_3 \text{MUEHR*Experience} + \alpha \boldsymbol{X} + \varepsilon$$

where *Benefit* is one of the dichotomous outcome variables, *MUEHR* and *Experience* are the key independent variables, and $\boldsymbol{X}$ is a vector of control variables including physician and office characteristics that have been

related to EHR adoption and attitudes toward EHRs in previous research (DesRoches et al. 2008; Decker, Jamoom, and Sisk 2012) (listed in Table S1). We included these controls to assess the association between the key independent variables and perceived EHR benefits holding other factors related to attitudes toward EHRs constant. We included the interaction between Meaningful Use EHR and 2 or more years EHR experience to assess the hypothesis that these two factors in combination are associated with higher probability of reporting benefits than either factor alone. All analyses were conducted using Stata 12.1 (College Station, TX, USA), using weights to account for nonresponse and adjusting standard errors for the complex survey design.

Because the direction and statistical significance of effects in nonlinear models with interaction terms cannot be interpreted directly from the coefficients, we calculated incremental effects for the key independent variables and predicted probabilities for combinations of the interaction term (Karaca-Mandic, Norton, and Dowd 2012). Specifically, to assess the hypothesis that Meaningful Use EHRs and EHR experience are independently associated with the probability of reporting clinical benefits from EHR use, we used Stata's post-estimation margins command to calculate the average incremental effects of having a Meaningful Use EHR (relative to other EHRs) and having 2 or more years of EHR experience (relative to 1 year or less) among all EHR adopters overall.

To assess the hypothesis that the combination of Meaningful Use EHR and longer EHR experience is associated with a greater probability of reporting clinical benefits than either factor alone, we used Stata's post-estimation margins command to calculate the average predicted probability of reporting the benefit for all combinations of the interaction (i.e., four groups of physicians, those with (1) Meaningful Use EHRs and greater EHR experience; (2) Meaningful Use EHRs and less EHR experience; (3) other EHRs and greater EHR experience; and (4) other EHRs and less EHR experience).

RESULTS

EHR Characteristics of EHR Adopters

Of EHR adopters, 76 percent reported that their EHR met Meaningful Use criteria and eight in ten EHR adopters reported 2 or more years of experience with an EHR system (Table 1).

Table 1: Electronic Health Record (EHR) Characteristics and Perceived Clinical Benefits of EHR Use among Office-Based Physicians with Any EHR (n = 1,727)

EHR characteristics (%)	
EHR meets Meaningful Use criteria	
No or uncertain	24
Yes	76
Length of experience with any EHR system	
1 year or less	18
2 years or more	82
Share of physicians who report that the use of their EHR system has led to clinical benefits (%)	
Overall, enhanced patient care	78
Helped you access a patient's chart remotely (e.g., to work from home)	81
Alerted you to a potential medication error	65
Alerted you to critical lab values	62
Helped you order more on-formulary drugs (as opposed to off-formulary drugs)	46
Reminded you to provide preventive care (e.g., vaccine, cancer screening)	47
Reminded you to provide care that meets clinical guidelines for patients with chronic conditions	45
Helped you order fewer tests due to better availability of lab results	37
Helped you identify needed lab tests (such as HbA1c or LDL)	33
Facilitated direct communication with a patient (e.g., email or secure messaging)	30

Source: CDC/NCHS, Physician Workflow study, 2011. Estimates are unadjusted.

Reported Clinical Benefits of EHR Use

Nearly 8 in 10 physicians with EHRs reported that overall, use of their EHR enhanced patient care (78 percent) (Table 1). There was variation in the extent to which EHR adopters reported that EHR use led to the nine measures of specific benefits. The majority reported that EHR use helped them to access a patient's chart remotely (81 percent), alerted them to a potential medication error (65 percent), and alerted them to critical lab values (62 percent). For the remaining six measures, between 30 and 46 percent of EHR adopters reported that EHR use provided clinical benefits.

Relationship between Whether EHR Met Meaningful Use Criteria and EHR Experience and Reported Clinical Benefits of EHR Use

Controlling for physician and practice characteristics, having an EHR that met Meaningful Use criteria and EHR experience were independently associated with a higher probability of reporting clinical benefits (Table 2).

Table 2: Incremental Effects of Electronic Health Record (EHR) Characteristics on Probability That Physician Reported EHR Use Led to Clinical Benefit (n = 1,727)

	Overall, Enhanced Patient Care	*Helped You Access a Patient's Chart Remotely (e.g., to work from home)*	*Alerted You to a Potential Medication Error*	*Alerted You to Critical Lab Values*	*Helped You Order More on-Formulary Drugs (as opposed to off-formulary drugs)*	*Reminded You to Provide Preventive Care (E.g., vaccine, cancer screening)*	*Reminded You to Provide Care that Meets Clinical Guidelines for Patients with Chronic Conditions*	*Helped You Order Fewer Tests Due to Better Availability of Lab Results*	*Helped You Identify Needed Lab Tests (such as HbA1c or LDL)*	*Facilitated Direct Communication with a Patient (e.g., email or secure messaging)*
EHR meets Meaningful Use criteria										
Yes (vs No or Unknown)	9.9**	5.4	3.4	9.4*	11.3**	11.1**	20.1**	15.3**	14.2**	11.3**
Length of experience with any EHR system										
2 years or more (vs. 1 year or less)	25.4**	16.4**	16.0**	12.1**	7.6	14.9**	9.6	9.0	12.5**	9.7*

Note. **(*) Significantly different from zero at $p < .01$ (.05). Estimates are the percentage point difference (compared to reference category) in predicted probability of reporting EHR use led to the clinical benefit.
Source: CDC/NCHS, Physician Workflow study, 2011.

For example, physicians with EHRs that met Meaningful Use criteria were 9.9 percentage points more likely than physicians with other EHRs to report their EHR overall enhanced patient care, and physicians with 2 years or more EHR experience were 25.4 percentage points more likely to report this benefit than physicians with less EHR experience.

Physicians with EHRs that met Meaningful Use criteria and 2 or more years of EHR experience were the most likely to report EHR benefits across almost all measures examined (Table 3). Of physicians in

Table 3: Predicted Probability that Physician Reported Electronic Health Record (EHR) Use Led to Clinical Benefit, by EHR Characteristics (n = 1,727)

	EHR Meets Meaningful Use Criteria			
	No or Uncertain		*Yes*	
	0–1 years EHR Experience, %	*2+ years EHR Experience, %*	*0–1 years EHR Experience, %*	*2+ years EHR Experience, %*
Overall, enhanced patient care	45**	75**	57**	85
Helped you access a patient's chart remotely (e.g., to work from home)	70	77**	65**	87
Alerted you to a potential medication error	48	64	48**	70
Alerted you to critical lab values	57	54**	43**	70
Helped you order more on-formulary drugs (as opposed to off-formulary drugs)	42	36**	37*	52
Reminded you to provide preventive care (e.g., vaccine, cancer screening)	41	36**	29**	55
Reminded you to provide care that meets clinical guidelines for patients with chronic conditions	33	28**	34**	54
Helped you order fewer tests due to better availability of lab results	28	25**	25**	45
Helped you identify needed lab tests (such as HbA1c or LDL)	22	22**	20**	41
Facilitated direct communication with a patient (e.g., email or secure messaging)	18	21**	17**	37
Percent of physicians with EHRs	4	20	14	62

Note. **(*) Significantly different from EHR meets Meaningful Use criteria with 2 or more years EHR experience at $p < .01$ (.05).
Source: CDC/NCHS, Physician Workflow study, 2011.

this group, 85 percent reported that EHR use had enhanced patient care overall and at least half reported EHR benefits for six of the nine specific measures.

DISCUSSION

In this nationally representative sample, over three-quarters of EHR adopters reported that EHR use enhanced patient care overall. To varying degrees, EHR adopters reported benefits of EHR use for specific measures of clinical quality, patient safety, and efficiency. Physicians using EHRs that met Meaningful Use criteria who had two or more years of EHR experience were the most likely to report clinical benefits.

Meaningful Use criteria require that EHRs include functionalities considered critical to improving quality such as capturing key patient data, electronic ordering, and clinical decision support (Bryan and Boren 2008; Berner 2009; Holden 2010). Using an EHR that met Meaningful Use criteria was significantly associated with reporting clinical benefits enabled by these functionalities. Our findings are consistent with prior studies finding higher reported EHR satisfaction and benefits among physicians using relatively robust EHRs (DesRoches et al. 2008; Menachemi et al. 2010; Coffman et al. 2012).

We also found that EHR experience was associated with a higher probability of reporting EHR benefits. Our findings may reflect an EHR learning curve; over time, physicians may integrate the EHR more fully into their workflow and may be more equipped to use advanced EHR functionalities (El-Kareh et al. 2009; Devine et al. 2010; Shield et al. 2010; Holroyd-Leduc et al. 2011; Doyle et al. 2012). Our findings might also reflect an "early adopter" phenomenon whereby physicians who were most likely to perceive EHRs as having clinical benefits adopted EHRs at an earlier point in time. Finally, physicians who did not experience EHR benefits may have stopped using EHRs prior to our study period; if this is the case, it would contribute to the observed association between EHR experience and perceived benefits.

Our findings have implications for HITECH programs and other initiatives to support EHR adoption and use. In particular, benefits reported at relatively low rates in 2011 point to opportunities for policies and programs to support EHR optimization. The least commonly reported EHR benefits related to measures potentially dependent on physicians' ability to

exchange and use structured laboratory data (i.e., reductions in duplicate lab test ordering and identifying needed lab tests) and use EHRs to engage with patients (i.e., facilitating direct communication with patients). While information exchange with labs and patients was relatively low in 2011 (Patel et al. 2013), electronic exchange and patient engagement are emphasized in requirements for Stage 2 Meaningful Use, which will begin in 2014 (Centers for Medicare and Medicaid Services 2012). For example, to be certified for Stage 2, EHRs must be able exchange data with EHRs developed by other vendors, incorporate lab results into the EHR as structured data, and provide patients the ability to view, download, and transmit their health information (Office of the National Coordinator for Health Information Technology 2012).

Our study has important limitations. The findings reflect physician perceptions of EHR benefits; clinical quality and outcomes were not independently measured. Our measure of EHRs meeting Meaningful Use criteria was not directly validated, although our estimate was consistent with another government survey (Office of Inspector General 2012) and our findings were robust to sensitivity analyses. Although estimates were weighted to minimize nonresponse bias, residual bias may lead to overestimates of positive perceptions regarding EHR benefits. Given the cross-sectional nature of this analysis, we cannot conclude that our findings represent causal relationships between having an EHR that meets Meaningful Use criteria and EHR experience and EHR benefits. Our findings are representative of office-based physicians who used EHRs in 2011; these relationships may not be present among later adopters who begin using EHRs in coming years.

Conclusion

In 2011, most physicians using EHRs had adopted systems that met Meaningful Use criteria and had at least 2 years of experience with any EHR. A majority of EHR adopters reported EHR use led to a variety of clinical benefits and enhanced patient care. Physicians with EHRs that met Meaningful Use criteria and greater EHR experience were the most likely to report clinical benefits. To the extent that physician perceptions accurately reflect improvements in care delivery, the adoption of EHRs meeting Meaningful Use criteria and growing experience with EHR systems could improve quality of care.

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NOTES

1. In all, 8.4 percent answered "no," 14.4 percent answered "uncertain," and 1.4 percent did not answer the question.
2. Among physicians with complete responses to both the NAMCS Electronic Health Record Survey (NEHRS) and the Physician Workflow study, we conducted a sensitivity analysis using data collected in the NEHRS to construct a measure of whether the physician reported 9 of the 15 computerized capabilities in the core Meaningful Use requirements. Overall conclusions were consistent and differences were generally larger than main results reported in the text.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Table S1: Physician and Practice Characteristics of Office-Based Physicians with Any EHR (n = 1,727).

Table S2: Incremental Effects of EHR Characteristics on Probability that Physicians Reported EHR Use Led to Clinical Benefit (n = 1,727).